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Sensitivity Analysis of Dredge Fleet Scheduling

An Undergraduate Honors College Thesis
in the

Department of Industrial Engineering
College of Engineering University of
Arkansas Fayetteville, AR

By

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April 24, 2015

This thesis is approved.

Thesis Advisor:

Thesis Committee:

Abstract

Each year, the U.S. Army Corps of Engineers (USACE) is tasked with conducting maintenance dredging at hundreds of project sites throughout the country. The USACE must take into account factors such as environmental windows, increased transportation distances, increased operational time because of reduced vessel speeds, and personnel availability constraints. Environmental windows are intended to minimize the environmental impact of dredging while protecting biological resources and their habitats from potentially detrimental effects. The objective of this research is to perform sensitivity analysis of the performance of this model (cubic yards dredged) and how it is impacted by individual environmental window elimination and changes in the available budget and dredge vessel resources. The first sensitivity analysis studies how the removal of an individual restricted period can lead to system wide productivity gains. The results indicate that the removal of a restricted period related to the California Least Tern on the Channel Harbor Island, CA job allows for the greatest improvement in cubic yards dredged with an increase of 16.60% over the baseline. The second sensitivity analysis examines the impact on the objective value (total cubic yards dredged) when the budget is increased or decreased by 10% and also altering the number of dredge resources between thirty lower production dredges and fifteen higher production dredges. The results show that an increase or decrease in the system budget has a much greater impact on the objective value whereas the number of dredge vessel resources and their production rates do not greatly affect the objective value. The sensitivity analyses performed in this honors thesis provides additional evidence to support the fact that dredge productivity gains can be realized when specific restricted periods are removed and/or the system budget is increased.

Contents

1 Introduction

The U.S. Army Corps of Engineers (USACE) has the federal navigation mission to "provide safe, reliable, efficient, effective and environmentally sustainable waterborne transportation systems for movement of commerce, national security needs, and recreation" (U.S. Army Corps of Engineers, n.d.). The USACE manages a widespread navigation portfolio including 1067 navigation projects, 929 navigation structures, 844 bridges, and 171 lock sites across nearly 12,000 miles of commercial, navigable U.S. inland and intracoastal waterways (U.S. Army Corps of Engineers, 2012). Using a combination of government dredge fleets and individual contracts with private industry, the Corps is tasked with conducting maintenance dredging at hundreds of project sites throughout the country. The decision of assigning individual dredge fleets to navigation projects is made at the Corps District-level which sometimes results in jobs within different Districts competing for the same fleet resources. This competition for dredge funding at the district-level can potentially create inefficiencies for the entire portfolio of jobs. It was anticipated that a system level decision model to assign dredging jobs would help optimize the limited budget and eliminate the inefficiencies with the current funding model. Research conducted by Nachtmann et al. (2013) introduced a system-level formulation to optimize the decision of allocating dredge resources to projects under system constraints such as environmental windows, dredge resource cost and availability, and District-level project requirements.

In an effort to reduce flood and storm damage, maintain navigable channels, and re-establish marine ecosystems, the USACE annually funds over $1.5 billion in engineering, construction, and operations and maintenance (O&M) of the nation's waterways, ports, and harbors (Pfenning & DeLoach, 2011). Over the past several decades, an increase in total cost associated with annual O&M dredging system wide has occurred without a proportionate increase in total volume of material dredged. It is widely believed that this disproportionate increase in total cost is the result of system inefficiencies due to a variety of factors including environmental work windows, increased transportation distances,

increased operational time because of reduced vessel speeds, and personnel availability constraints (Dickerson et al., 1998). Environmental windows are defined by the USACE as temporal constraints placed upon the method of dredging or dredged material disposal operations in order to protect biological resources or their habitats from potentially detrimental effects (Dickerson et al., 1998). These environmental windows intended to minimize the environmental impact of dredging can be connected to considerable cost increments across the system-wide navigation portfolio. The objective of our dredge scheduling decision model is to maximize the cumulative cubic yards dredged during a calendar year while adhering to budgetary, scheduling, and environmental restrictions. The research objective of this honors thesis is to perform a sensitivity analysis of the performance of this model and how it is impacted by individual environmental window elimination and changes in the available budget and dredge vessel resources.

2 Problem Definition

Previous research has been conducted by Nachtmann et al. (2013) in which a mathematical modeling approach was implemented to optimize the decision of allocating dredge resources to projects system-wide while adhering to system constraints such as environmental windows, dredge resource cost and availability, and District-level project requirements. Taking the decision of allocating dredge resources to projects from the District-level to a system wide level helps to eliminate inefficiencies for annual USACE O&M dredging of navigation projects. Research previously conducted offered quantitative evidence to support that less restrictive environmental windows allows for productivity gains system wide (Nachtmann et al., 2013). To further study if relaxed environmental windows lead to productivity gains, this thesis conducts two sensitivity analyses. The first sensitivity analysis examines which restricted periods have the most significant impact on overall dredge program efficiency. This will be investigated by assigning each individual restricted period an additional variable entitled window ID. The

mathematical model will remove one window ID, corresponding to a restricted period, each time the program runs a complete cycle. This allows one to determine how the removal of each restricted period separately affects the overall objective function to determine if significant productivity gains can be realized by removing a particular restricted period. The second sensitivity analysis examines how changes in the system budget and available dredge vessel resources will affect the overall dredge program efficiency. This will be investigated by individually altering the system wide budget by a 10% increase and a 10% decrease and changing the available dredge resources from thirty dredges to fifteen dredges. This will allow one to determine how increasing or decreasing the budget impacts the objective function value, and study whether it is more efficient to introduce thirty small dredge vessels with lower daily production rates or fifteen large dredge vessels with higher production rates. It is hypothesized that the elimination of certain restricted periods will greatly increase cumulative system wide cubic yards dredged during a calendar year (objective function value). Additionally, it is believed that a 10% increase in the system budget will allow for greater productivity (more cubic yards dredged) and more dredge projects being completed.

3 Sensitivity Analysis

This research seeks to examine how removing a single restricted period window affects the total system wide volume dredged and which restricted periods have the greatest impact on the objective function performance. To perform the sensitivity analysis, the original selection of 116 jobs that was implemented in the previously performed research was utilized (Nachtmann et al., 2013). The mathematical model was altered to cycle through the restricted periods using a FOR loop and for each instance in which the restricted period corresponded to the window ID, the restricted period was removed. The corresponding results were written into a data file that displayed the associated objective value in cubic yards dredged along with the total dredge time, travel time, and idle time corresponding

to each instance based on which restricted period was removed in the cycle. The sensitivity analysis shows that in twenty-seven instances, the removal of a restricted period increased the overall cubic yards dredged system wide compared to the baseline objective function value (30,696,002 cubic yards) when no restricted periods are removed. These results are shown in Table 1, and the baseline case is the shaded row in Table 1. The full results are shown in Table 6 of the Appendix.

Table 1. Top Program Results for Omitting One Restricted Period at a Time

Experiment No	Number of RPs	Objective Function Value (cubic yards)	Solution Time (sec)	Total Dredge Time (sec)	Total Travel Time (sec)	Total Idle Time (sec)	RP	% Increase
1	138	35,791,122	24.446	3741	1945	1156	19	16.60%
1	138	32,880,165	23.696	5252	1194	496	17	7.12%
1	138	32,566,644	23.509	4892	1933	696	11	6.09%
1	138	31,325,492	23.977	4499	2548	640	57	2.05%
1	138	31,299,258	23.915	4738	1977	619	28	1.97%
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1	138	31,147,931	23.665	5059	1991	429	84	1.47%
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1	138	31,024,842	23.649	4545	1806	320	47	1.07%
1	138	31,016,264	23.743	4055	2123	636	83	1.04%
1	138	30,992,681	23.696	5355	1762	908	58	0.97%
1	138	30,909,971	23.572	4685	2026	489	27	0.70%
1	138	30,896,643	23.853	4309	2309	1000	87	0.65%
1	138	30,878,313	23.868	4441	2009	542	24	0.59%
1	138	30,851,403	23.993	5391	2157	620	29	0.51%
1	138	30,823,651	23.759	3805	2874	735	37	0.42%
1	138	30,812,416	23.556	5423	2219	423	79	0.38%
1	138	30,810,942	23.837	6095	1175	300	6	0.37%
1	138	30,806,678	23.728	4458	1955	603	40	0.36%
1	138	30,806,402	24.18	4073	2217	841	53	0.36%
1	138	30,785,173	23.431	4014	2121	571	74	0.29%
1	138	30,779,094	23.899	4921	2209	797	2	0.27%
1	138	30,756,467	23.899	4483	1924	940	54	0.20%
1	138	30,724,975	24.086	4515	2183	1021	77	0.09%
1	138	30,712,260	24.07	4453	2718	630	31	0.05%
1	138	30,703,115	24.102	4278	2064	721	15	0.02%
1	138	30,696,002	24.819	4940	2743	737	0	0.00%

Examining the results in Table 1 shows that the baseline objective value is 30,696,002 cubic yards, and the removal of Restricted Period 19 (RP 19) yields an objective value of 35,791,122 cubic yards (16.60% increase in the total cubic yards dredged). Similarly, removing RPs 17 and 11, (protecting marine turtles including the Green Turtle, Kemp's Ridley, and Loggerhead) result in increases of 7.12% and 6.09% total cubic yards dredged respectively. The increases in total cubic yards dredged for the other twenty-four instances do not lead to a valuable improvement over the baseline. RP 19 impacts a dredging job on the West Coast in Channel Islands Harbor, CA and is in effect from April 1 to September 15 in order to protect the California Least Tern, a species of bird.

Further examination into the detailed solutions of the baseline instance when no restricted periods were removed and the greatest improvement instance when RP 19 was removed reveals that 100 dredging jobs were completed when no RPs were removed and 98 dredging jobs were completed when RP 19 was removed. The increase in the objective function value when RP 19 is removed is the result of completing dredge jobs with larger job sizes than in the baseline instance. Even though two less jobs are completed with the removal of RP 19, the total job size for the 98 jobs completed is 1,441,264 cubic yards greater than the baseline instance (no restricted period removed). This increase in cubic yards dredged is what accounts for the 16.60% increase in the objective value function over the baseline.

Additionally, this research seeks to determine the impact on the objective value (total cubic yards dredged) when the system wide budget was increased or decreased by 10% and also altering the number of dredge resources between thirty lower production dredges and fifteen higher production dredges. This sensitivity analysis examines the impact on the objective value for six different instances with changes in the budget and dredge resources when all restricted periods are included. The first two instances to examine utilize the model's normal budget, $167,259,009, with thirty dredges or fifteen dredges which will be considered the baseline instances. The objective value (total cubic yards dredged

in a calendar year) utilizing the normal budget with thirty dredges results in 31,289,991 cubic yards dredged and with fifteen dredges results in 31,616,386 cubic yards. It is believed that the slightly lower objective value for the baseline instance with thirty dredges over fifteen dredges is just a byproduct of the mathematical model not being able to run as long and therefore not being able to reach optimality. A summary of these results are shown in Table 2, and the full results for each of the six instances are shown in Tables 7-12 of the Appendix.

Table 2. Total Cubic Yards Dredged for Changes in Budget and Dredge Resources

	30 Dredges	30 Dredges, % Change	15 Dredges	15 Dredges, % Change
10% Budget Increase	32,160,271	2.78%	32,160,271	1.72%
Normal Budget	31,289,991	0.00%	31,616,386	0.00%
10% Budget Decrease	30,305,849	-3.15%	30,466,525	-3.64%

In order to examine the impact the budget has on the objective value, the next two instances will observe how a 10% budget increase will impact the total amount dredged in a calendar year. A 10% budget increases yields a budget of $183,984,910 and the experiments with thirty dredges or fifteen dredges both result in objective values of 32,160,271 cubic yards dredged. It is possible the budget increase of 10% allows the solution for both instances of the experiment for thirty dredges and fifteen dredges to be improved by a practically important amount during the solution time of the experiment.

The last two instances to examine in order to observe how the budget affects the objective value is to decrease the budget by 10% which yields a budget of $150,533,108. In the experiment utilizing a decreased budget with thirty dredge vessels yields an objective value of 30,305,849 cubic yards and the experiment with fifteen dredge vessels yields an objective value of 30,466,525 cubic yards. Compared to the baseline instances, decreasing the budget by 10% results in a 3.15% decrease

and 3.64% decrease in the total cubic yards dredged for thirty dredges and fifteen dredges respectively. A 10% decrease in the system budget results in less dredging jobs being completed; however the difference between thirty dredges and fifteen dredges does not seem to have a significant impact on the overall system wide cubic yards dredged. In summary, a 10% budget increase results in the dredge system improving by a practically important amount regardless of whether thirty lower production dredges are used or fifteen higher production dredges are used. A 10% budget decrease results in a 3.15% decrease and 3.64% decrease in the objective value for thirty dredges and fifteen dredges respectively. When factoring in a budget decrease, there is not a large impact on the total cubic yards dredged between utilizing thirty lower production dredges or fifteen higher production dredges. The increase or decrease in budget plays a much more significant role in the overall objective function than the number of dredge resources and their production rates.

4 Concluding Remarks

Previous research revealed that a systems-based approach to scheduling dredge resources to projects results in increased efficiencies for annual USACE dredging of navigation projects (Nachtmann et al., 2013). This thesis conducts a sensitivity analysis to learn more about system wide efficiencies that could be gained to increase the total volume of material dredged. This work contributes quantitative evidence to support the productivity gains that can be realized with the removal of particular restricted periods. Specifically, the removal of the California Least Tern RP on the Channel Harbor Island, CA job allows for the greatest improvement in cubic yards dredged with an increase of 16.60%, followed by the removal of the marine turtle RPs (17 and 11) with increases of 7.12% and 6.09% respectively. The removal of these RPs allows for larger sized projects to be completed resulting in a positive impact on the overall amount dredged. Additionally, this work supports the fact that an increase or decrease in the system budget has a greater impact on the overall cubic yards dredged, whereas the number of dredge

resources and their production rates does not significantly affect the objective function which is shown in Table 2. The sensitivity analyses performed in this honors thesis provides additional evidence to support the fact that dredge productivity gains can be realized when specific environmental windows are removed.

This work provides a basis for directing future research efforts towards a more in-depth examination of restricted periods and the impact they have on dredge program efficiency. Future research could examine setting restricted periods to be 50% functional or 75% functional which would allow dredge vessels to dredge during part of the restricted period. Additionally, one could investigate the impact on program efficiency if more than one dredge vessel is allowed to work on a single job at a time.

A Appendix

Table A.1. Production Rates for 30 Dredges in Cubic Yards per Day

1238
1301
1637
1962
1989
2296
2375
2709
2855
3311
3481
3728
3941
4532
5941
6837
6965
8332
8443
9007
10436
10478
10959
12347
12882
15556
17080
17282
17537
19245
21726
24618
29147
32841
33870
34716
35324

38665
41463
66418

Table A.2. Production Rates for 15 Dredges in Cubic Yards per Day

6837
6965
8332
8443
9007
10436
10478
10959
12347
12882
15556
17080
17282
17537
19245
21726
24618
29147
32841
33870
34716
35324
38665
41463
66418

Table A.3. Experiment Info (Top to Bottom: Number of Jobs, Number of Dredge Vessels, Planning Horizon, Number of Restricted Periods, Budget)

116
30
365
138
167,259,009

Table A.4. Job Sizes in Cubic Yards and Average Cost for each of the 116 Jobs respectively

439726	3201839
900709	5533068
4376	46441
2267192	14477345
466950	2989574
2001129	2523736
39308	1016772
178088	791822
451796	1261920
6723	275719
2472603	6685844
102032	1242273
85093	2409673
277836	786758
2890491	3793482
179782	1612871
116357	2307509
396079	909977
5413965	5452500
67221	1231600
13252	226709
35672	321356
45533	142900
808778	1502833
397516	1745287
243898	1489330
38598	306499
201116	1122792
117090	719437
80528	733469
191015	1708370
261440	1058165
1117205	9124564
63380	2260932
186551	1183650
668425	2073745
41563	311454
577424	1543516
147811	2153095
1038304	1534705

42408	283559
167704	1416099
1494596	4048374
1189684	12991774
225664	1427334
283367	1151256
67571	380810
80000	1579250
122930	864000
102424	751304
74288	519202
261769	1845812
59190	419900
40729	530127
681961	1419778
944417	1496737
1505100	5388149
1282956	2509501
577711	2972600
156607	1104938
30523	420827
544338	2338424
123064	9739760
174603	998309
26937	644784
67578	318000
217888	967081
34637	302055
723937	2628970
44401	334654
119668	1891959
1193406	2009923
252670	251296
192277	980108
82949	748816
46686	481990
4510	102371
26009	144042
59003	690963
572395	2405442
95491	723544

21003	178236
83378	146508
32688	453483
295967	1881768
231639	1709816
833305	2509084
120808	900546
145537	942239
261985	1363696
127064	310965
572249	4008166
216709	864890
47674	284901
22153	159881
306546	5944930
633833	8574738
64118	1162671
42577	389861
49558	2497492
64262	950325
212214	1588367
1037987	4895841
229090	456000
55762	326262
105955	443959
1086812	1486174
97935	442630
50777	331749
9868	66150
53971	258289
323758	1262279
1171297	6527537
33939	4687087
75373	468695
561192	2499452

Table A.5. Restricted Periods (First Column: Window ID, Second Column: Job ID, Third and Fourth Columns: Restricted Period in Days)

1	1	152	274
2	2	305	365

2	2	1	120
3	3	166	365
3	3	1	60
4	4	335	365
4	4	1	213
5	5	152	334
6	6	91	334
7	7	91	334
8	9	91	273
9	10	105	335
10	11	91	105
11	11	105	334
12	11	335	365
12	11	1	90
13	12	288	365
13	12	1	151
14	13	60	181
15	13	244	365
16	14	105	335
17	15	91	334
18	16	288	365
18	16	1	151
19	19	91	258
20	20	1	91
21	20	91	213
22	20	91	274
23	20	152	334
24	21	32	273
25	24	105	335
26	25	32	273
27	28	181	365
27	28	1	60
28	29	197	365
28	29	1	134
29	31	91	273
30	32	305	365
30	32	1	166
31	33	15	273
32	34	166	258
33	35	60	334
34	35	319	365
34	35	1	74
35	35	335	365
35	35	1	90
36	36	152	304
37	36	305	365

37	36	1	151
38	37	181	365
38	37	1	60
39	38	74	166
40	38	151	365
40	38	1	89
41	40	91	334
42	41	166	365
42	41	1	60
43	42	32	105
44	42	121	212
45	44	319	365
45	44	1	74
46	44	335	365
46	44	1	90
47	44	335	365
47	44	1	105
48	46	46	181
49	47	152	274
50	48	152	258
51	49	91	258
52	50	91	181
53	51	181	365
53	51	1	60
54	52	91	334
55	52	152	274
56	53	288	365
56	53	1	181
57	56	91	334
58	56	305	365
58	56	1	212
59	57	305	365
59	57	1	212
60	58	91	334
61	59	91	334
62	59	152	274
63	60	60	258
64	60	91	258
65	62	121	305
66	63	60	151
67	63	74	151
68	63	91	166
69	63	244	304
70	64	152	334
71	65	213	365
71	65	1	120

72	67	335	365
72	67	1	212
73	68	91	227
74	68	152	334
75	71	319	365
75	71	1	74
76	72	91	334
77	73	74	135
78	74	32	212
79	74	288	365
79	74	1	212
80	75	319	365
80	75	1	74
81	75	335	365
81	75	1	90
82	75	335	365
82	75	1	105
83	78	166	365
83	78	1	60
84	79	74	166
85	80	32	243
86	81	335	365
86	81	1	151
87	82	105	335
88	85	305	365
88	85	1	212
89	86	74	258
90	87	32	181
91	87	32	212
92	87	32	243
93	87	74	212
94	87	121	181
95	87	121	304
96	87	152	250
97	87	182	273
98	87	258	365
98	87	1	212
99	87	274	365
99	87	1	151
100	87	288	365
100	87	1	212
101	87	305	365
101	87	1	135
102	87	335	365
102	87	1	59
103	87	335	365

103	87	1	151
104	87	335	365
104	87	1	181
105	87	335	365
105	87	1	243
106	87	335	365
106	87	1	303
107	88	335	365
107	88	1	151
108	89	335	365
108	89	1	151
109	91	305	365
109	91	1	166
110	92	152	258
111	93	152	274
112	94	105	335
113	95	166	365
113	95	1	60
114	97	319	365
114	97	1	74
115	98	196	258
116	99	181	365
116	99	1	60
117	100	74	258
118	102	335	365
118	102	1	212
119	103	319	365
119	103	1	74
120	104	305	334
121	106	105	335
122	107	60	258
123	107	74	258
124	107	91	258
125	108	135	319
126	109	288	365
126	109	1	181
127	110	31	181
128	111	105	335
129	113	152	334
130	113	32	212
131	113	91	244
132	113	91	319
133	113	91	334
134	113	121	181
135	113	152	274
136	114	335	365

136	114	1	243
137	115	105	335
138	116	135	319

Table A.6. Full Results for Omitting One Restricted Period at a Time

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1	138	30,851,403	23.993	5391	2157	620	29	0.51%
1	138	30,823,651	23.759	3805	2874	735	37	0.42%
1	138	30,812,416	23.556	5423	2219	423	79	0.38%
1	138	30,810,942	23.837	6095	1175	300	6	0.37%
1	138	30,806,678	23.728	4458	1955	603	40	0.36%
1	138	30,806,402	24.18	4073	2217	841	53	0.36%
1	138	30,785,173	23.431	4014	2121	571	74	0.29%
1	138	30,779,094	23.899	4921	2209	797	2	0.27%
1	138	30,756,467	23.899	4483	1924	940	54	0.20%
1	138	30,724,975	24.086	4515	2183	1021	77	0.09%
1	138	30,712,260	24.07	4453	2718	630	31	0.05%
1	138	30,703,115	24.102	4278	2064	721	15	0.02%
1	138	30,696,002	24.819	4940	2743	737	0	0.00%
1	138	30,696,002	23.665	4940	2743	737	10	0.00%
1	138	30,696,002	24.071	4940	2743	737	12	0.00%
1	138	30,696,002	23.759	4940	2743	737	21	0.00%
1	138	30,696,002	23.681	4940	2743	737	22	0.00%

1	138	30,696,002	23.54	4940	2743	737	34	0.00%
1	138	30,696,002	23.993	4940	2743	737	35	0.00%
1	138	30,696,002	23.454	4940	2743	737	46	0.00%
1	138	30,696,002	23.619	4940	2743	737	55	0.00%
1	138	30,696,002	22.932	4940	2743	737	62	0.00%
1	138	30,696,002	22.963	4940	2743	737	64	0.00%
1	138	30,696,002	23.119	4940	2743	737	67	0.00%
1	138	30,696,002	23.634	4940	2743	737	78	0.00%
1	138	30,696,002	23.322	4940	2743	737	81	0.00%
1	138	30,696,002	23.525	4940	2743	737	90	0.00%
1	138	30,696,002	23.384	4940	2743	737	91	0.00%
1	138	30,696,002	23.322	4940	2743	737	92	0.00%
1	138	30,696,002	23.587	4940	2743	737	93	0.00%
1	138	30,696,002	23.635	4940	2743	737	94	0.00%
1	138	30,696,002	23.649	4940	2743	737	96	0.00%
1	138	30,696,002	24.274	4940	2743	737	97	0.00%
1	138	30,696,002	23.072	4940	2743	737	98	0.00%
1	138	30,696,002	24.009	4940	2743	737	99	0.00%
1	138	30,696,002	23.805	4940	2743	737	100	0.00%
1	138	30,696,002	23.166	4940	2743	737	101	0.00%
1	138	30,696,002	23.525	4940	2743	737	102	0.00%
1	138	30,696,002	23.697	4940	2743	737	103	0.00%
1	138	30,696,002	23.088	4940	2743	737	104	0.00%
1	138	30,696,002	23.805	4940	2743	737	105	0.00%
1	138	30,696,002	23.51	4940	2743	737	106	0.00%
1	138	30,696,002	23.54	4940	2743	737	107	0.00%
1	138	30,696,002	23.696	4940	2743	737	108	0.00%
1	138	30,696,002	23.447	4940	2743	737	109	0.00%
1	138	30,696,002	23.712	4940	2743	737	110	0.00%
1	138	30,696,002	24.04	4940	2743	737	111	0.00%
1	138	30,696,002	23.54	4940	2743	737	112	0.00%
1	138	30,696,002	23.931	4940	2743	737	113	0.00%
1	138	30,696,002	24.352	4940	2743	737	114	0.00%
1	138	30,696,002	23.446	4940	2743	737	115	0.00%
1	138	30,696,002	23.806	4940	2743	737	116	0.00%
1	138	30,696,002	22.62	4940	2743	737	117	0.00%
1	138	30,696,002	23.213	4940	2743	737	118	0.00%
1	138	30,696,002	23.634	4940	2743	737	119	0.00%
1	138	30,696,002	24.508	4940	2743	737	120	0.00%
1	138	30,696,002	23.275	4940	2743	737	121	0.00%
1	138	30,696,002	23.15	4940	2743	737	122	0.00%

1	138	30,696,002	23.276	4940	2743	737	123	0.00%
1	138	30,696,002	23.571	4940	2743	737	124	0.00%
1	138	30,696,002	23.899	4940	2743	737	125	0.00%
1	138	30,696,002	23.931	4940	2743	737	126	0.00%
1	138	30,696,002	23.556	4940	2743	737	127	0.00%
1	138	30,696,002	22.994	4940	2743	737	128	0.00%
1	138	30,696,002	23.432	4940	2743	737	129	0.00%
1	138	30,696,002	23.559	4940	2743	737	130	0.00%
1	138	30,696,002	23.837	4940	2743	737	131	0.00%
1	138	30,696,002	23.572	4940	2743	737	132	0.00%
1	138	30,696,002	23.213	4940	2743	737	133	0.00%
1	138	30,696,002	23.446	4940	2743	737	134	0.00%
1	138	30,696,002	24.146	4940	2743	737	135	0.00%
1	138	30,696,002	23.588	4940	2743	737	136	0.00%
1	138	30,696,002	23.899	4940	2743	737	137	0.00%
1	138	30,696,002	23.665	4940	2743	737	138	0.00%
1	138	30,684,948	23.806	4822	1805	641	48	-0.04%
1	138	30,680,386	23.806	4708	1457	298	73	-0.05%
1	138	30,659,077	23.509	4302	1161	468	89	-0.12%
1	138	30,638,010	23.868	5054	2501	775	95	-0.19%
1	138	30,593,438	23.51	4452	2819	764	59	-0.33%
1	138	30,555,456	23.992	3223	2814	465	38	-0.46%
1	138	30,546,788	24.82	4021	2093	930	69	-0.49%
1	138	30,524,365	23.385	3440	2089	700	61	-0.56%
1	138	30,518,144	23.135	3472	2136	1106	30	-0.58%
1	138	30,505,262	23.619	4129	2012	700	14	-0.62%
1	138	30,501,072	24.086	3741	2423	693	82	-0.64%
1	138	30,496,213	23.842	4096	2012	865	26	-0.65%
1	138	30,480,170	24.149	4609	2205	559	71	-0.70%
1	138	30,461,062	24.32	3785	1924	503	18	-0.77%
1	138	30,460,955	23.9	4602	1985	517	85	-0.77%
1	138	30,453,765	24.461	4268	2498	834	3	-0.79%
1	138	30,436,211	23.915	4130	2711	819	43	-0.85%
1	138	30,431,636	23.385	5009	2991	646	23	-0.86%
1	138	30,428,086	24.305	3759	1833	584	4	-0.87%
1	138	30,397,799	23.54	4309	1877	732	86	-0.97%
1	138	30,386,255	23.166	4054	1468	959	42	-1.01%
1	138	30,372,601	24.321	4366	2494	790	80	-1.05%
1	138	30,351,647	24.227	4852	2335	881	49	-1.12%
1	138	30,296,163	23.821	4593	1687	460	75	-1.30%
1	138	30,289,932	23.135	5037	1983	376	56	-1.32%

1	138	30,273,446	23.025	3792	1729	716	13	-1.38%
1	138	30,270,773	23.774	4644	2564	571	70	-1.39%
1	138	30,256,579	24.227	5389	1847	568	52	-1.43%
1	138	30,231,366	23.65	4630	1733	1142	44	-1.51%
1	138	30,194,465	24.195	4434	2236	1412	20	-1.63%
1	138	30,106,240	23.509	3079	2357	729	41	-1.92%
1	138	30,084,711	23.791	4197	2442	377	32	-1.99%
1	138	30,020,708	23.525	4962	1425	556	51	-2.20%
1	138	30,020,076	23.868	5028	1321	814	68	-2.20%
1	138	30,017,585	22.917	4124	1755	738	8	-2.21%
1	138	30,012,134	24.18	3412	2231	844	88	-2.23%
1	138	30,008,489	23.946	5084	2316	877	5	-2.24%
1	138	29,980,546	24.039	4172	1740	675	60	-2.33%
1	138	29,939,860	23.884	4302	1929	306	9	-2.46%
1	138	29,893,079	24.087	6045	1437	229	1	-2.62%
1	138	29,883,932	24.024	4272	2164	597	66	-2.65%
1	138	29,871,517	23.681	4795	1441	342	36	-2.69%
1	138	29,843,032	22.822	5093	1962	788	7	-2.78%
1	138	29,824,470	23.353	5301	1408	846	25	-2.84%
1	138	29,813,187	23.135	5001	2012	590	63	-2.88%
1	138	29,805,898	23.493	4638	2319	537	45	-2.90%
1	138	29,783,717	23.603	4865	1812	856	65	-2.97%
1	138	29,743,323	23.337	4158	2265	758	50	-3.10%
1	138	29,643,811	23.79	5086	2465	464	33	-3.43%
1	138	29,638,097	23.712	3955	2148	1311	72	-3.45%

Table A.7. Full Results for Instance with Normal Budget and 30 Dredges

Experiment No	**Number of RPs**	**Objective Function Value (cubic yards)**	**Solution Time (sec)**	**Total Dredge Time (sec)**	**Total Travel Time (sec)**	**Total Idle Time (sec)**	**RP**	**% Change**
1	138	36,728,243	263.984	4443	2185	595	19	17.38%
1	138	34,111,961	263.827	4019	2570	1018	17	9.02%
1	138	33,513,312	263.36	4655	2141	704	11	7.11%
1	138	32,466,325	263.173	5149	2620	700	58	3.76%
1	138	32,440,216	264.404	4429	2856	937	57	3.68%
1	138	32,099,652	263.563	4680	1618	703	39	2.59%
1	138	32,052,298	263.5	5257	2357	1136	40	2.44%
1	138	31,969,895	264.265	3229	2041	707	37	2.17%
1	138	31,625,694	264.109	4273	2556	289	48	1.07%
1	138	31,616,386	263.562	4183	2390	1201	5	1.04%

1	138	31,616,386	263.875	4954	2277	691	15	1.04%
1	138	31,616,386	264.093	3510	2025	748	47	1.04%
1	138	31,616,386	263.297	3325	2046	874	61	1.04%
1	138	31,616,386	263.812	3664	2291	1429	86	1.04%
1	138	31,616,063	264.654	3565	2208	794	24	1.04%
1	138	31,610,995	264.015	4587	2325	1006	20	1.03%
1	138	31,596,069	264.983	3842	2070	698	53	0.98%
1	138	31,592,749	263.734	3562	1976	466	50	0.97%
1	138	31,592,749	263.203	3961	2599	700	54	0.97%
1	138	31,592,749	264.062	4013	1873	999	70	0.97%
1	138	31,591,576	263.874	4585	2231	401	76	0.96%
1	138	31,588,473	263.735	3162	1942	549	9	0.95%
1	138	31,588,473	262.985	4123	2280	288	13	0.95%
1	138	31,588,473	264.249	2919	2155	670	14	0.95%
1	138	31,588,473	263.547	4095	3077	812	18	0.95%
1	138	31,588,473	264.639	4094	1813	1262	29	0.95%
1	138	31,588,473	263.874	3332	2050	774	43	0.95%
1	138	31,588,473	263.469	5075	2789	1060	56	0.95%
1	138	31,588,473	263.624	2988	2887	421	68	0.95%
1	138	31,588,473	263.797	3715	1879	323	69	0.95%
1	138	31,588,473	263.641	3117	1801	641	75	0.95%
1	138	31,588,473	263.859	4565	2027	613	79	0.95%
1	138	31,588,473	264.093	3449	2030	423	87	0.95%
1	138	31,588,473	264.373	3140	1748	522	89	0.95%
1	138	31,587,346	264.264	5169	3058	603	3	0.95%
1	138	31,587,346	264.265	4397	2318	521	27	0.95%
1	138	31,587,346	264.264	3950	1795	696	28	0.95%
1	138	31,580,746	264.109	4368	2769	591	82	0.93%
1	138	31,570,140	263.937	5100	2050	575	42	0.90%
1	138	31,567,795	263.125	4133	2745	543	8	0.89%
1	138	31,566,629	264.327	4681	2503	867	2	0.88%
1	138	31,566,629	264.421	5231	2142	737	4	0.88%
1	138	31,566,629	263.656	4253	2336	1202	23	0.88%
1	138	31,566,629	264.389	4264	2409	815	41	0.88%
1	138	31,564,805	263.344	5076	1922	764	85	0.88%
1	138	31,558,141	263.656	3381	2071	503	36	0.86%
1	138	31,557,209	264.17	4259	1833	972	38	0.85%
1	138	31,557,209	263.672	5493	2476	1099	59	0.85%
1	138	31,557,209	263.562	3152	2117	600	71	0.85%
1	138	31,557,209	263.968	4412	2663	943	72	0.85%
1	138	31,557,209	263.219	4980	2376	738	80	0.85%

1	138	31,543,874	263.703	4357	2192	756	73	0.81%
1	138	31,541,207	263.501	5673	2407	318	44	0.80%
1	138	31,532,226	263.765	3619	2697	790	52	0.77%
1	138	31,532,226	263.735	5108	2710	335	63	0.77%
1	138	31,532,226	263.796	5113	2071	856	84	0.77%
1	138	31,526,961	263.189	3857	1785	723	25	0.76%
1	138	31,526,961	262.673	4730	2087	954	51	0.76%
1	138	31,526,961	263.796	5384	2423	557	65	0.76%
1	138	31,526,961	262.814	4831	3026	551	66	0.76%
1	138	31,511,692	263.702	3742	2512	543	26	0.71%
1	138	31,510,513	264.155	4957	2367	755	45	0.70%
1	138	31,501,281	263.625	4527	2683	993	83	0.68%
1	138	31,479,249	263.797	4754	2685	525	32	0.60%
1	138	31,473,093	264.311	3133	1627	490	60	0.59%
1	138	31,454,229	262.673	5015	2300	800	7	0.52%
1	138	31,449,872	264.109	2906	1530	368	88	0.51%
1	138	31,398,188	263.5	4978	2375	821	74	0.35%
1	138	31,374,996	264.358	5631	1747	825	33	0.27%
1	138	31,373,449	263.781	4223	1944	1223	31	0.27%
1	138	31,364,850	263.266	4316	2548	662	49	0.24%
1	138	31,346,279	262.517	4223	1909	899	16	0.18%
1	138	31,343,722	263.204	3990	2492	704	77	0.17%
1	138	31,289,991	264.795	4615	2116	1092	0	0.00%
1	138	31,289,991	264.03	4615	2116	1092	10	0.00%
1	138	31,289,991	263.219	4615	2116	1092	12	0.00%
1	138	31,289,991	264.389	4615	2116	1092	21	0.00%
1	138	31,289,991	264.639	4615	2116	1092	22	0.00%
1	138	31,289,991	263.469	4615	2116	1092	34	0.00%
1	138	31,289,991	264.03	4615	2116	1092	35	0.00%
1	138	31,289,991	263.593	4615	2116	1092	46	0.00%
1	138	31,289,991	263.485	4615	2116	1092	55	0.00%
1	138	31,289,991	263.952	4615	2116	1092	62	0.00%
1	138	31,289,991	263.094	4615	2116	1092	64	0.00%
1	138	31,289,991	263.641	4615	2116	1092	67	0.00%
1	138	31,289,991	264.592	4615	2116	1092	78	0.00%
1	138	31,289,991	263.562	4615	2116	1092	81	0.00%
1	138	31,289,991	263.953	4615	2116	1092	90	0.00%
1	138	31,289,991	263.671	4615	2116	1092	91	0.00%
1	138	31,289,991	263.953	4615	2116	1092	92	0.00%
1	138	31,289,991	263.157	4615	2116	1092	93	0.00%
1	138	31,289,991	263.734	4615	2116	1092	94	0.00%

1	138	31,289,991	264.467	4615	2116	1092	95	0.00%
1	138	31,289,991	263.843	4615	2116	1092	96	0.00%
1	138	31,289,991	264.078	4615	2116	1092	97	0.00%
1	138	31,289,991	263.78	4615	2116	1092	98	0.00%
1	138	31,289,991	263.859	4615	2116	1092	99	0.00%
1	138	31,289,991	263.485	4615	2116	1092	100	0.00%
1	138	31,289,991	263.64	4615	2116	1092	101	0.00%
1	138	31,289,991	263.547	4615	2116	1092	102	0.00%
1	138	31,289,991	263.984	4615	2116	1092	103	0.00%
1	138	31,289,991	263.406	4615	2116	1092	104	0.00%
1	138	31,289,991	263.188	4615	2116	1092	105	0.00%
1	138	31,289,991	263.282	4615	2116	1092	106	0.00%
1	138	31,289,991	263.001	4615	2116	1092	107	0.00%
1	138	31,289,991	263.859	4615	2116	1092	108	0.00%
1	138	31,289,991	263.843	4615	2116	1092	109	0.00%
1	138	31,289,991	263.313	4615	2116	1092	110	0.00%
1	138	31,289,991	264.405	4615	2116	1092	111	0.00%
1	138	31,289,991	263.25	4615	2116	1092	112	0.00%
1	138	31,289,991	263.687	4615	2116	1092	113	0.00%
1	138	31,289,991	263.22	4615	2116	1092	114	0.00%
1	138	31,289,991	263.203	4615	2116	1092	115	0.00%
1	138	31,289,991	263.048	4615	2116	1092	116	0.00%
1	138	31,289,991	263.453	4615	2116	1092	117	0.00%
1	138	31,289,991	263.469	4615	2116	1092	118	0.00%
1	138	31,289,991	264.093	4615	2116	1092	119	0.00%
1	138	31,289,991	263.126	4615	2116	1092	120	0.00%
1	138	31,289,991	263.64	4615	2116	1092	121	0.00%
1	138	31,289,991	264.718	4615	2116	1092	122	0.00%
1	138	31,289,991	263.645	4615	2116	1092	123	0.00%
1	138	31,289,991	263.758	4615	2116	1092	124	0.00%
1	138	31,289,991	264.123	4615	2116	1092	125	0.00%
1	138	31,289,991	264.063	4615	2116	1092	126	0.00%
1	138	31,289,991	263.727	4615	2116	1092	127	0.00%
1	138	31,289,991	263.742	4615	2116	1092	128	0.00%
1	138	31,289,991	263.196	4615	2116	1092	129	0.00%
1	138	31,289,991	263.279	4615	2116	1092	130	0.00%
1	138	31,289,991	263.5	4615	2116	1092	131	0.00%
1	138	31,289,991	263.411	4615	2116	1092	132	0.00%
1	138	31,289,991	263.691	4615	2116	1092	133	0.00%
1	138	31,289,991	263.69	4615	2116	1092	134	0.00%
1	138	31,289,991	264.266	4615	2116	1092	135	0.00%

1	138	31,289,991	263.199	4615	2116	1092	136	0.00%
1	138	31,289,991	264.043	4615	2116	1092	137	0.00%
1	138	31,289,991	263.7	4615	2116	1092	138	0.00%
1	138	31,280,690	263.578	3171	2234	407	30	-0.03%
1	138	30,903,366	264.14	4006	2110	831	1	-1.24%
1	138	30,810,942	264.343	6095	1175	300	6	-1.53%

Table A.8. Full Results for Instance with Normal Budget and 15 Dredges

Experiment No	Number of RPs	Objective Function Value (cubic yards)	Solution Time (sec)	Total Dredge Time (sec)	Total Travel Time (sec)	Total Idle Time (sec)	RP	% Change
1	138	36,739,836	261.238	2922	1486	261	19	16.21%
1	138	34,274,860	261.082	2637	2327	172	17	8.41%
1	138	33,734,356	261.175	2798	1701	338	11	6.70%
1	138	33,494,435	261.253	2803	2056	254	6	5.94%
1	138	32,480,803	261.144	2691	2037	317	57	2.73%
1	138	32,480,803	261.082	2729	2175	154	58	2.73%
1	138	32,187,033	261.128	2619	1390	350	37	1.80%
1	138	32,150,651	261.317	2799	1345	323	36	1.69%
1	138	32,119,458	261.16	2730	1476	690	40	1.59%
1	138	32,113,810	261.238	2725	1525	396	39	1.57%
1	138	31,738,819	261.254	2699	2002	379	33	0.39%
1	138	31,628,797	261.176	2498	1613	751	15	0.04%
1	138	31,628,797	261.223	2614	2156	351	28	0.04%
1	138	31,625,694	261.114	2678	1895	203	4	0.03%
1	138	31,625,694	261.347	2592	1840	145	9	0.03%
1	138	31,625,694	261.004	2632	2212	145	16	0.03%
1	138	31,625,694	261.035	2587	2312	219	25	0.03%
1	138	31,625,694	261.222	2565	1266	315	29	0.03%
1	138	31,625,694	261.16	2621	2117	351	42	0.03%
1	138	31,625,694	261.66	2582	2334	293	49	0.03%
1	138	31,625,694	261.3	2702	2027	264	50	0.03%
1	138	31,625,694	261.269	2666	1664	212	51	0.03%
1	138	31,625,694	261.597	2541	1640	599	56	0.03%
1	138	31,625,694	261.145	2622	1906	275	59	0.03%
1	138	31,625,694	261.597	2585	1556	306	73	0.03%
1	138	31,625,694	261.551	2676	2025	119	84	0.03%
1	138	31,625,694	261.409	2596	1308	445	87	0.03%
1	138	31,625,694	261.409	2603	1439	501	89	0.03%
1	138	31,619,165	261.129	2630	1647	375	7	0.01%

1	138	31,619,165	261.301	2570	1900	311	30	0.01%
1	138	31,619,165	261.534	2754	2000	332	31	0.01%
1	138	31,617,658	261.207	2444	1950	455	8	0.00%
1	138	31,617,658	261.191	2703	2266	241	13	0.00%
1	138	31,617,658	261.16	2544	1652	530	18	0.00%
1	138	31,617,658	261.3	2448	1838	465	23	0.00%
1	138	31,617,658	261.145	2613	2110	325	24	0.00%
1	138	31,617,658	261.191	2583	2104	373	32	0.00%
1	138	31,617,658	261.254	2719	1723	362	43	0.00%
1	138	31,617,658	261.254	2705	2097	420	47	0.00%
1	138	31,617,658	261.504	2558	2083	598	52	0.00%
1	138	31,617,658	261.488	2577	1772	325	63	0.00%
1	138	31,617,658	261.269	2573	2443	318	65	0.00%
1	138	31,617,658	261.207	2583	1187	738	66	0.00%
1	138	31,617,658	261.518	2609	2214	292	69	0.00%
1	138	31,617,658	261.457	2597	2173	431	70	0.00%
1	138	31,617,658	261.363	2759	1406	326	74	0.00%
1	138	31,617,658	261.363	2705	1558	449	75	0.00%
1	138	31,617,658	261.3	2531	1914	429	77	0.00%
1	138	31,617,658	261.098	2648	1949	343	79	0.00%
1	138	31,617,658	261.363	2560	1698	727	86	0.00%
1	138	31,617,658	261.192	2652	2049	380	88	0.00%
1	138	31,617,524	261.597	2631	2182	209	54	0.00%
1	138	31,616,386	261.196	2578	2005	508	0	0.00%
1	138	31,616,386	261.285	2649	2234	288	2	0.00%
1	138	31,616,386	261.316	2521	1562	565	5	0.00%
1	138	31,616,386	261.348	2578	2005	508	10	0.00%
1	138	31,616,386	261.301	2578	2005	508	12	0.00%
1	138	31,616,386	261.347	2578	2005	508	21	0.00%
1	138	31,616,386	261.207	2578	2005	508	22	0.00%
1	138	31,616,386	261.238	2729	1564	420	26	0.00%
1	138	31,616,386	261.066	2621	2177	403	27	0.00%
1	138	31,616,386	261.223	2578	2005	508	34	0.00%
1	138	31,616,386	261.284	2578	2005	508	35	0.00%
1	138	31,616,386	261.238	2673	2476	153	41	0.00%
1	138	31,616,386	261.316	2702	2170	231	45	0.00%
1	138	31,616,386	261.254	2578	2005	508	46	0.00%
1	138	31,616,386	261.565	2708	1792	189	48	0.00%
1	138	31,616,386	261.144	2524	1434	533	53	0.00%
1	138	31,616,386	261.363	2578	2005	508	55	0.00%
1	138	31,616,386	261.129	2648	2261	300	60	0.00%

1	138	31,616,386	261.378	2578	2005	508	62	0.00%
1	138	31,616,386	261.363	2578	2005	508	64	0.00%
1	138	31,616,386	261.737	2578	2005	508	67	0.00%
1	138	31,616,386	261.066	2560	1381	539	71	0.00%
1	138	31,616,386	261.176	2347	1893	331	72	0.00%
1	138	31,616,386	261.16	2658	1924	370	76	0.00%
1	138	31,616,386	261.519	2578	2005	508	78	0.00%
1	138	31,616,386	261.753	2578	2005	508	81	0.00%
1	138	31,616,386	261.378	2731	1904	464	85	0.00%
1	138	31,616,386	261.223	2578	2005	508	90	0.00%
1	138	31,616,386	261.176	2578	2005	508	91	0.00%
1	138	31,616,386	261.222	2578	2005	508	92	0.00%
1	138	31,616,386	261.254	2578	2005	508	93	0.00%
1	138	31,616,386	261.409	2578	2005	508	94	0.00%
1	138	31,616,386	261.55	2578	2005	508	95	0.00%
1	138	31,616,386	261.363	2578	2005	508	96	0.00%
1	138	31,616,386	261.566	2578	2005	508	97	0.00%
1	138	31,616,386	261.472	2578	2005	508	98	0.00%
1	138	31,616,386	261.222	2578	2005	508	99	0.00%
1	138	31,616,386	261.3	2578	2005	508	100	0.00%
1	138	31,616,386	261.456	2578	2005	508	101	0.00%
1	138	31,616,386	261.666	2578	2005	508	102	0.00%
1	138	31,616,386	261.628	2578	2005	508	103	0.00%
1	138	31,616,386	261.191	2578	2005	508	104	0.00%
1	138	31,616,386	261.597	2578	2005	508	105	0.00%
1	138	31,616,386	261.456	2578	2005	508	106	0.00%
1	138	31,616,386	261.441	2578	2005	508	107	0.00%
1	138	31,616,386	261.862	2578	2005	508	108	0.00%
1	138	31,616,386	261.847	2578	2005	508	109	0.00%
1	138	31,616,386	261.284	2578	2005	508	110	0.00%
1	138	31,616,386	261.348	2578	2005	508	111	0.00%
1	138	31,616,386	261.347	2578	2005	508	112	0.00%
1	138	31,616,386	261.519	2578	2005	508	113	0.00%
1	138	31,616,386	261.599	2578	2005	508	114	0.00%
1	138	31,616,386	261.518	2578	2005	508	115	0.00%
1	138	31,616,386	261.365	2578	2005	508	116	0.00%
1	138	31,616,386	261.668	2578	2005	508	117	0.00%
1	138	31,616,386	261.643	2578	2005	508	118	0.00%
1	138	31,616,386	261.873	2578	2005	508	119	0.00%
1	138	31,616,386	261.482	2578	2005	508	120	0.00%
1	138	31,616,386	261.176	2578	2005	508	121	0.00%

1	138	31,616,386	261.368	2578	2005	508	122	0.00%
1	138	31,616,386	261.494	2578	2005	508	123	0.00%
1	138	31,616,386	261.3	2578	2005	508	124	0.00%
1	138	31,616,386	261.418	2578	2005	508	125	0.00%
1	138	31,616,386	261.372	2578	2005	508	126	0.00%
1	138	31,616,386	261.399	2578	2005	508	127	0.00%
1	138	31,616,386	261.548	2578	2005	508	128	0.00%
1	138	31,616,386	261.557	2578	2005	508	129	0.00%
1	138	31,616,386	261.782	2578	2005	508	130	0.00%
1	138	31,616,386	261.534	2578	2005	508	131	0.00%
1	138	31,616,386	261.753	2578	2005	508	132	0.00%
1	138	31,616,386	261.444	2578	2005	508	133	0.00%
1	138	31,616,386	261.352	2578	2005	508	134	0.00%
1	138	31,616,386	261.387	2578	2005	508	135	0.00%
1	138	31,616,386	261.496	2578	2005	508	136	0.00%
1	138	31,616,386	261.337	2578	2005	508	137	0.00%
1	138	31,616,386	261.213	2578	2005	508	138	0.00%
1	138	31,611,053	261.363	2527	1170	569	1	-0.02%
1	138	31,611,053	261.284	2550	2043	442	44	-0.02%
1	138	31,607,607	261.284	2537	1784	536	3	-0.03%
1	138	31,607,607	261.269	2689	2455	66	14	-0.03%
1	138	31,607,607	261.348	2609	2028	402	38	-0.03%
1	138	31,607,607	261.238	2557	1759	343	61	-0.03%
1	138	31,607,607	261.258	2510	1709	299	82	-0.03%
1	138	31,604,368	261.176	2438	1794	584	68	-0.04%
1	138	31,602,397	261.24	2608	1424	637	83	-0.04%
1	138	31,595,852	261.409	2545	1546	559	80	-0.06%
1	138	31,570,898	261.223	2579	1446	771	20	-0.14%

Table A.9. Full Results for Instance with 10% Budget Increase and 30 Dredges

Experiment No	Number of RPs	Objective Function Value (cubic yards)	Solution Time (sec)	Total Dredge Time (sec)	Total Travel Time (sec)	Total Idle Time (sec)	RP	% Change
1	138	37,497,741	264.124	4381	1617	1224	19	16.60%
1	138	35,001,204	263.188	5680	2957	502	17	8.83%
1	138	34,519,936	263.64	5683	2327	637	11	7.34%
1	138	34,161,400	263.862	4277	2704	651	6	6.22%
1	138	33,104,688	263.547	4619	2384	1030	57	2.94%
1	138	33,104,688	264.093	5511	2559	561	58	2.94%
1	138	32,828,696	262.689	4892	2304	458	36	2.08%

1	138	32,828,696	263.172	5069	2608	894	37	2.08%
1	138	32,737,695	262.622	5577	2640	1033	39	1.80%
1	138	32,737,695	263.531	4498	2202	824	40	1.80%
1	138	32,346,822	263.703	4152	2148	858	33	0.58%
1	138	32,160,271	264.203	5397	2810	492	0	0.00%
1	138	32,160,271	265.214	5997	1644	527	1	0.00%
1	138	32,160,271	264.448	6079	1611	361	2	0.00%
1	138	32,160,271	263.244	3979	2187	629	3	0.00%
1	138	32,160,271	264.079	5088	2890	1116	4	0.00%
1	138	32,160,271	264.582	5952	1513	448	5	0.00%
1	138	32,160,271	263.391	5925	1613	423	7	0.00%
1	138	32,160,271	263.188	4962	2998	485	8	0.00%
1	138	32,160,271	263.937	5300	2733	1014	9	0.00%
1	138	32,160,271	264.124	5397	2810	492	10	0.00%
1	138	32,160,271	264.483	5397	2810	492	12	0.00%
1	138	32,160,271	264.03	5941	1445	723	13	0.00%
1	138	32,160,271	263.345	4970	3048	897	14	0.00%
1	138	32,160,271	264.311	5846	1375	290	15	0.00%
1	138	32,160,271	264.467	5928	1451	396	16	0.00%
1	138	32,160,271	264.311	4750	2026	858	18	0.00%
1	138	32,160,271	263.891	4435	2631	1086	20	0.00%
1	138	32,160,271	264.061	5397	2810	492	21	0.00%
1	138	32,160,271	263.235	5397	2810	492	22	0.00%
1	138	32,160,271	264.233	5871	1397	423	23	0.00%
1	138	32,160,271	263.984	5088	3120	1011	24	0.00%
1	138	32,160,271	264.53	4290	2791	1376	25	0.00%
1	138	32,160,271	263.016	5318	1660	506	26	0.00%
1	138	32,160,271	263.672	4773	1812	542	27	0.00%
1	138	32,160,271	263.687	3849	2810	1096	28	0.00%
1	138	32,160,271	263.453	4852	2165	777	29	0.00%
1	138	32,160,271	262.908	4237	2560	648	30	0.00%
1	138	32,160,271	263.032	2840	1982	633	31	0.00%
1	138	32,160,271	262.548	4976	2513	757	32	0.00%
1	138	32,160,271	263.282	5397	2810	492	34	0.00%
1	138	32,160,271	263.219	5397	2810	492	35	0.00%
1	138	32,160,271	263.345	5134	2286	651	38	0.00%
1	138	32,160,271	263.422	6013	1635	734	41	0.00%
1	138	32,160,271	263.874	5970	1613	490	42	0.00%
1	138	32,160,271	263.048	5875	1501	637	43	0.00%
1	138	32,160,271	263.048	5926	1647	433	44	0.00%
1	138	32,160,271	263.827	5927	1560	614	45	0.00%

1	138	32,160,271	263.391	5397	2810	492	46	0.00%
1	138	32,160,271	264.031	5699	1910	929	47	0.00%
1	138	32,160,271	263.266	5951	1507	467	48	0.00%
1	138	32,160,271	263.781	5964	1410	351	49	0.00%
1	138	32,160,271	263.266	5952	1466	336	50	0.00%
1	138	32,160,271	263.422	4469	2871	662	51	0.00%
1	138	32,160,271	263.437	4518	1857	888	52	0.00%
1	138	32,160,271	263.407	3286	2634	664	53	0.00%
1	138	32,160,271	263.89	5252	2808	872	54	0.00%
1	138	32,160,271	263.032	5397	2810	492	55	0.00%
1	138	32,160,271	263.64	5041	3307	735	56	0.00%
1	138	32,160,271	263.329	6184	1586	461	59	0.00%
1	138	32,160,271	263.905	6049	1532	530	60	0.00%
1	138	32,160,271	262.923	5447	2416	1267	61	0.00%
1	138	32,160,271	263.672	5397	2810	492	62	0.00%
1	138	32,160,271	263.749	5954	1655	355	63	0.00%
1	138	32,160,271	263.251	5397	2810	492	64	0.00%
1	138	32,160,271	263.297	4973	3136	702	65	0.00%
1	138	32,160,271	263.719	4045	2795	1418	66	0.00%
1	138	32,160,271	263.5	5397	2810	492	67	0.00%
1	138	32,160,271	263.734	3909	2126	727	68	0.00%
1	138	32,160,271	262.907	5728	2664	303	69	0.00%
1	138	32,160,271	264.108	5946	1373	572	70	0.00%
1	138	32,160,271	263.969	4620	2097	469	71	0.00%
1	138	32,160,271	262.142	5866	1538	524	72	0.00%
1	138	32,160,271	263.438	4853	2966	1305	73	0.00%
1	138	32,160,271	263.781	5819	1702	471	74	0.00%
1	138	32,160,271	264.093	3764	1283	678	75	0.00%
1	138	32,160,271	263.25	4484	2167	606	76	0.00%
1	138	32,160,271	263.781	4300	2521	768	77	0.00%
1	138	32,160,271	263.999	5397	2810	492	78	0.00%
1	138	32,160,271	262.845	4701	3064	1003	79	0.00%
1	138	32,160,271	263.61	4056	2511	1030	80	0.00%
1	138	32,160,271	263.562	5397	2810	492	81	0.00%
1	138	32,160,271	263.157	5894	1753	677	82	0.00%
1	138	32,160,271	263.36	5927	1505	524	83	0.00%
1	138	32,160,271	263.983	5103	3354	390	84	0.00%
1	138	32,160,271	263.282	4927	2114	973	85	0.00%
1	138	32,160,271	262.595	5860	1575	454	86	0.00%
1	138	32,160,271	263.734	5424	2641	663	87	0.00%
1	138	32,160,271	263.921	5961	1381	460	88	0.00%

1	138	32,160,271	263.547	4702	2378	599	89	0.00%
1	138	32,160,271	263.922	5397	2810	492	90	0.00%
1	138	32,160,271	263.64	5397	2810	492	91	0.00%
1	138	32,160,271	264.108	5397	2810	492	92	0.00%
1	138	32,160,271	263.579	5397	2810	492	93	0.00%
1	138	32,160,271	263.094	5397	2810	492	94	0.00%
1	138	32,160,271	263.391	5397	2810	492	95	0.00%
1	138	32,160,271	263.999	5397	2810	492	96	0.00%
1	138	32,160,271	262.923	5397	2810	492	97	0.00%
1	138	32,160,271	263.75	5397	2810	492	98	0.00%
1	138	32,160,271	263.952	5397	2810	492	99	0.00%
1	138	32,160,271	263.251	5397	2810	492	100	0.00%
1	138	32,160,271	262.829	5397	2810	492	101	0.00%
1	138	32,160,271	263.453	5397	2810	492	102	0.00%
1	138	32,160,271	263.578	5397	2810	492	103	0.00%
1	138	32,160,271	263.719	5397	2810	492	104	0.00%
1	138	32,160,271	263.718	5397	2810	492	105	0.00%
1	138	32,160,271	262.907	5397	2810	492	106	0.00%
1	138	32,160,271	263.516	5397	2810	492	107	0.00%
1	138	32,160,271	263.157	5397	2810	492	108	0.00%
1	138	32,160,271	264.062	5397	2810	492	109	0.00%
1	138	32,160,271	263.312	5397	2810	492	110	0.00%
1	138	32,160,271	263.656	5397	2810	492	111	0.00%
1	138	32,160,271	264.031	5397	2810	492	112	0.00%
1	138	32,160,271	264.046	5397	2810	492	113	0.00%
1	138	32,160,271	263.75	5397	2810	492	114	0.00%
1	138	32,160,271	263.469	5397	2810	492	115	0.00%
1	138	32,160,271	263.359	5397	2810	492	116	0.00%
1	138	32,160,271	263.313	5397	2810	492	117	0.00%
1	138	32,160,271	263.594	5397	2810	492	118	0.00%
1	138	32,160,271	263.437	5397	2810	492	119	0.00%
1	138	32,160,271	263.672	5397	2810	492	120	0.00%
1	138	32,160,271	264.062	5397	2810	492	121	0.00%
1	138	32,160,271	263.562	5397	2810	492	122	0.00%
1	138	32,160,271	263.219	5397	2810	492	123	0.00%
1	138	32,160,271	263.61	5397	2810	492	124	0.00%
1	138	32,160,271	263.562	5397	2810	492	125	0.00%
1	138	32,160,271	263.297	5397	2810	492	126	0.00%
1	138	32,160,271	264.202	5397	2810	492	127	0.00%
1	138	32,160,271	263.485	5397	2810	492	128	0.00%
1	138	32,160,271	264.093	5397	2810	492	129	0.00%

1	138	32,160,271	263.422	5397	2810	492	130	0.00%
1	138	32,160,271	263.687	5397	2810	492	131	0.00%
1	138	32,160,271	263.407	5397	2810	492	132	0.00%
1	138	32,160,271	263.281	5397	2810	492	133	0.00%
1	138	32,160,271	263.719	5397	2810	492	134	0.00%
1	138	32,160,271	264.03	5397	2810	492	135	0.00%
1	138	32,160,271	264.28	5397	2810	492	136	0.00%
1	138	32,160,271	263.75	5397	2810	492	137	0.00%
1	138	32,160,271	263.672	5397	2810	492	138	0.00%

Table A.10. Full Results for Instance with 10% Budget Increase and 15 Dredges

Experiment No	Number of RPs	Objective Function Value (cubic yards)	Solution Time (sec)	Total Dredge Time (sec)	Total Travel Time (sec)	Total Idle Time (sec)	RP	% Change
1	138	37,497,741	261.131	3021	2054	69	19	16.60%
1	138	35,001,204	261.41	2886	2173	194	17	8.83%
1	138	34,519,936	261.166	2728	1706	423	11	7.34%
1	138	34,161,400	261.123	2863	1714	494	6	6.22%
1	138	33,104,688	261.303	2801	1474	407	57	2.94%
1	138	33,104,688	261.048	2762	2330	274	58	2.94%
1	138	32,828,696	261.286	2782	2199	150	36	2.08%
1	138	32,828,696	261.233	2776	1912	422	37	2.08%
1	138	32,737,695	261.295	2757	1886	165	39	1.80%
1	138	32,737,695	261.227	2880	2015	374	40	1.80%
1	138	32,346,822	261.364	2481	1695	631	33	0.58%
1	138	32,160,271	261.679	2691	2043	357	0	0.00%
1	138	32,160,271	261.351	2717	1481	430	1	0.00%
1	138	32,160,271	261.365	2577	2060	366	2	0.00%
1	138	32,160,271	261.458	2615	1502	402	3	0.00%
1	138	32,160,271	261.278	2813	1908	356	4	0.00%
1	138	32,160,271	261.305	2709	1957	368	5	0.00%
1	138	32,160,271	261.818	2684	2113	222	7	0.00%
1	138	32,160,271	261.428	2741	2041	334	8	0.00%
1	138	32,160,271	261.405	2705	2039	189	9	0.00%
1	138	32,160,271	261.323	2691	2043	357	10	0.00%
1	138	32,160,271	261.438	2691	2043	357	12	0.00%
1	138	32,160,271	261.171	2591	2054	394	13	0.00%
1	138	32,160,271	261.646	2682	1815	230	14	0.00%
1	138	32,160,271	261.603	2749	1619	391	15	0.00%
1	138	32,160,271	261.522	2621	1683	604	16	0.00%

1	138	32,160,271	261.399	2641	1731	425	18	0.00%
1	138	32,160,271	261.235	2764	1941	393	20	0.00%
1	138	32,160,271	261.293	2691	2043	357	21	0.00%
1	138	32,160,271	261.177	2691	2043	357	22	0.00%
1	138	32,160,271	261.56	2665	1700	248	23	0.00%
1	138	32,160,271	261.608	2654	2226	350	24	0.00%
1	138	32,160,271	261.444	2800	1544	434	25	0.00%
1	138	32,160,271	261.347	2694	2214	423	26	0.00%
1	138	32,160,271	261.317	2701	2187	155	27	0.00%
1	138	32,160,271	261.399	2781	2186	207	28	0.00%
1	138	32,160,271	261.717	2625	1813	174	29	0.00%
1	138	32,160,271	261.084	2665	2015	354	30	0.00%
1	138	32,160,271	261.389	2804	2029	211	31	0.00%
1	138	32,160,271	261.199	2553	1851	339	32	0.00%
1	138	32,160,271	261.412	2691	2043	357	34	0.00%
1	138	32,160,271	261.329	2691	2043	357	35	0.00%
1	138	32,160,271	261.353	2629	1917	164	38	0.00%
1	138	32,160,271	261.237	2766	1999	149	41	0.00%
1	138	32,160,271	261.314	2603	1258	500	42	0.00%
1	138	32,160,271	261.336	2728	1408	613	43	0.00%
1	138	32,160,271	261.226	2670	2171	97	44	0.00%
1	138	32,160,271	261.178	2585	1616	585	45	0.00%
1	138	32,160,271	261.331	2691	2043	357	46	0.00%
1	138	32,160,271	261.382	2591	1962	392	47	0.00%
1	138	32,160,271	261.367	2670	1856	311	48	0.00%
1	138	32,160,271	261.584	2772	2305	143	49	0.00%
1	138	32,160,271	261.563	2736	1710	281	50	0.00%
1	138	32,160,271	261.512	2703	2237	14	51	0.00%
1	138	32,160,271	261.615	2761	1520	361	52	0.00%
1	138	32,160,271	261.194	2574	1698	458	53	0.00%
1	138	32,160,271	261.142	2742	1672	246	54	0.00%
1	138	32,160,271	261.688	2691	2043	357	55	0.00%
1	138	32,160,271	261.557	2580	1992	271	56	0.00%
1	138	32,160,271	261.49	2696	2082	284	59	0.00%
1	138	32,160,271	261.37	2583	2278	269	60	0.00%
1	138	32,160,271	261.486	2799	1508	453	61	0.00%
1	138	32,160,271	261.064	2691	2043	357	62	0.00%
1	138	32,160,271	261.397	2753	1502	479	63	0.00%
1	138	32,160,271	261.43	2691	2043	357	64	0.00%
1	138	32,160,271	261.886	2615	1993	146	65	0.00%
1	138	32,160,271	261.669	2767	1783	395	66	0.00%

1	138	32,160,271	261.34	2691	2043	357	67	0.00%
1	138	32,160,271	261.367	2626	1633	365	68	0.00%
1	138	32,160,271	261.522	2597	1961	393	69	0.00%
1	138	32,160,271	261.623	2669	1942	537	70	0.00%
1	138	32,160,271	261.45	2789	1336	607	71	0.00%
1	138	32,160,271	261.536	2601	2386	253	72	0.00%
1	138	32,160,271	261.938	2517	2022	372	73	0.00%
1	138	32,160,271	261.461	2480	1765	360	74	0.00%
1	138	32,160,271	261.761	2699	1834	511	75	0.00%
1	138	32,160,271	261.312	2707	2027	261	76	0.00%
1	138	32,160,271	261.181	2606	1482	485	77	0.00%
1	138	32,160,271	261.039	2691	2043	357	78	0.00%
1	138	32,160,271	261.278	2820	1769	539	79	0.00%
1	138	32,160,271	261.634	2779	1442	509	80	0.00%
1	138	32,160,271	261.649	2691	2043	357	81	0.00%
1	138	32,160,271	261.718	2876	1600	513	82	0.00%
1	138	32,160,271	261.212	2713	2084	208	83	0.00%
1	138	32,160,271	261.301	2713	2085	389	84	0.00%
1	138	32,160,271	261.876	2752	2017	138	85	0.00%
1	138	32,160,271	261.441	2772	1668	354	86	0.00%
1	138	32,160,271	261.173	2553	1405	278	87	0.00%
1	138	32,160,271	261.039	2668	2139	250	88	0.00%
1	138	32,160,271	261.562	2555	1733	293	89	0.00%
1	138	32,160,271	261.63	2691	2043	357	90	0.00%
1	138	32,160,271	261.734	2691	2043	357	91	0.00%
1	138	32,160,271	261.391	2691	2043	357	92	0.00%
1	138	32,160,271	261.415	2691	2043	357	93	0.00%
1	138	32,160,271	261.514	2691	2043	357	94	0.00%
1	138	32,160,271	261.773	2691	2043	357	95	0.00%
1	138	32,160,271	261.313	2691	2043	357	96	0.00%
1	138	32,160,271	261.403	2691	2043	357	97	0.00%
1	138	32,160,271	261.682	2691	2043	357	98	0.00%
1	138	32,160,271	261.359	2691	2043	357	99	0.00%
1	138	32,160,271	261.644	2691	2043	357	100	0.00%
1	138	32,160,271	261.697	2691	2043	357	101	0.00%
1	138	32,160,271	261.4	2691	2043	357	102	0.00%
1	138	32,160,271	261.645	2691	2043	357	103	0.00%
1	138	32,160,271	261.681	2691	2043	357	104	0.00%
1	138	32,160,271	261.33	2691	2043	357	105	0.00%
1	138	32,160,271	261.532	2691	2043	357	106	0.00%
1	138	32,160,271	261.877	2691	2043	357	107	0.00%

1	138	32,160,271	261.461	2691	2043	357	108	0.00%
1	138	32,160,271	261.349	2691	2043	357	109	0.00%
1	138	32,160,271	261.558	2691	2043	357	110	0.00%
1	138	32,160,271	261.702	2691	2043	357	111	0.00%
1	138	32,160,271	261.675	2691	2043	357	112	0.00%
1	138	32,160,271	261.463	2691	2043	357	113	0.00%
1	138	32,160,271	261.524	2691	2043	357	114	0.00%
1	138	32,160,271	261.903	2691	2043	357	115	0.00%
1	138	32,160,271	261.619	2691	2043	357	116	0.00%
1	138	32,160,271	261.652	2691	2043	357	117	0.00%
1	138	32,160,271	261.241	2691	2043	357	118	0.00%
1	138	32,160,271	261.819	2691	2043	357	119	0.00%
1	138	32,160,271	261.469	2691	2043	357	120	0.00%
1	138	32,160,271	261.607	2691	2043	357	121	0.00%
1	138	32,160,271	261.743	2691	2043	357	122	0.00%
1	138	32,160,271	261.397	2691	2043	357	123	0.00%
1	138	32,160,271	261.564	2691	2043	357	124	0.00%
1	138	32,160,271	261.641	2691	2043	357	125	0.00%
1	138	32,160,271	261.973	2691	2043	357	126	0.00%
1	138	32,160,271	261.745	2691	2043	357	127	0.00%
1	138	32,160,271	261.632	2691	2043	357	128	0.00%
1	138	32,160,271	261.636	2691	2043	357	129	0.00%
1	138	32,160,271	261.347	2691	2043	357	130	0.00%
1	138	32,160,271	261.423	2691	2043	357	131	0.00%
1	138	32,160,271	261.51	2691	2043	357	132	0.00%
1	138	32,160,271	261.717	2691	2043	357	133	0.00%
1	138	32,160,271	261.66	2691	2043	357	134	0.00%
1	138	32,160,271	261.422	2691	2043	357	135	0.00%
1	138	32,160,271	261.564	2691	2043	357	136	0.00%
1	138	32,160,271	261.752	2691	2043	357	137	0.00%
1	138	32,160,271	261.609	2691	2043	357	138	0.00%

Table A.11. Full Results for Instance with 10% Budget Decrease and 30 Dredges

Experiment No	Number of RPs	Objective Function Value (cubic yards)	Solution Time (sec)	Total Dredge Time (sec)	Total Travel Time (sec)	Total Idle Time (sec)	RP	% Change
1	138	35,460,339	263.763	3848	1489	917	19	17.01%
1	138	32,678,704	263.926	3124	2263	478	17	7.83%
1	138	32,345,149	264.012	4198	1734	963	6	6.73%
1	138	32,200,837	263.864	4095	2297	298	11	6.25%

1	138	31,267,226	263.977	4769	1866	833	58	3.17%
1	138	31,219,482	263.258	3917	1731	1113	57	3.01%
1	138	31,073,268	264.089	4272	1957	698	37	2.53%
1	138	30,983,644	264.098	3930	2436	925	39	2.24%
1	138	30,971,988	263.976	3325	2411	677	40	2.20%
1	138	30,704,830	264.222	4608	2233	977	36	1.32%
1	138	30,619,708	264.326	3958	2150	786	33	1.04%
1	138	30,539,682	263.922	4894	2179	914	32	0.77%
1	138	30,536,461	262.842	3210	1558	706	44	0.76%
1	138	30,536,424	264.007	4488	2408	695	71	0.76%
1	138	30,535,189	263.649	3827	1730	655	41	0.76%
1	138	30,531,010	264.211	4908	2170	223	15	0.74%
1	138	30,525,888	264.212	4139	2317	905	75	0.73%
1	138	30,525,041	263.755	4589	2609	746	66	0.72%
1	138	30,522,526	263.53	2893	1362	691	87	0.71%
1	138	30,520,487	263.852	4652	1865	745	1	0.71%
1	138	30,506,434	263.92	4388	2184	813	88	0.66%
1	138	30,497,275	263.223	4277	2034	1111	80	0.63%
1	138	30,497,275	264.019	4417	2408	742	85	0.63%
1	138	30,492,054	263.375	3841	2101	579	27	0.61%
1	138	30,486,220	264.366	4509	2503	590	79	0.60%
1	138	30,486,220	264.447	4275	2570	973	89	0.60%
1	138	30,484,494	264.21	5193	2148	471	83	0.59%
1	138	30,483,418	264.089	4613	1981	964	86	0.59%
1	138	30,463,387	263.566	4279	2663	1080	23	0.52%
1	138	30,463,013	263.79	3275	1859	718	16	0.52%
1	138	30,444,191	264.014	4086	2136	1063	3	0.46%
1	138	30,442,065	263.995	4628	2642	786	54	0.45%
1	138	30,429,822	263.88	4966	2303	919	70	0.41%
1	138	30,426,106	263.705	3863	2455	814	24	0.40%
1	138	30,414,669	263.728	4482	2528	602	8	0.36%
1	138	30,413,398	263.956	4163	1898	1141	13	0.35%
1	138	30,411,696	263.074	4515	1745	669	28	0.35%
1	138	30,397,411	263.895	4577	2311	686	65	0.30%
1	138	30,355,444	263.594	4044	1838	822	76	0.16%
1	138	30,353,936	263.679	4461	1693	432	25	0.16%
1	138	30,349,831	263.653	5049	1992	750	21	0.15%
1	138	30,349,831	263.625	5049	1992	750	22	0.15%
1	138	30,349,831	264.249	5049	1992	750	34	0.15%
1	138	30,349,831	263.373	5049	1992	750	93	0.15%
1	138	30,349,831	263.506	5049	1992	750	105	0.15%

1	138	30,349,831	263.666	5049	1992	750	106	0.15%
1	138	30,349,831	263.59	5049	1992	750	111	0.15%
1	138	30,349,831	263.785	5049	1992	750	112	0.15%
1	138	30,349,831	263.133	5049	1992	750	115	0.15%
1	138	30,349,831	263.415	5049	1992	750	132	0.15%
1	138	30,349,831	263.886	5049	1992	750	137	0.15%
1	138	30,305,849	263.987	4277	2358	708	0	0.00%
1	138	30,305,849	264.091	4277	2358	708	10	0.00%
1	138	30,305,849	263.89	4277	2358	708	12	0.00%
1	138	30,305,849	263.806	4277	2358	708	35	0.00%
1	138	30,305,849	263.898	4277	2358	708	46	0.00%
1	138	30,305,849	263.517	4277	2358	708	55	0.00%
1	138	30,305,849	264.235	4277	2358	708	62	0.00%
1	138	30,305,849	263.634	4277	2358	708	64	0.00%
1	138	30,305,849	263.957	4277	2358	708	67	0.00%
1	138	30,305,849	263.746	4277	2358	708	78	0.00%
1	138	30,305,849	263.885	4277	2358	708	81	0.00%
1	138	30,305,849	263.712	4277	2358	708	90	0.00%
1	138	30,305,849	263.685	4277	2358	708	91	0.00%
1	138	30,305,849	264.017	4277	2358	708	92	0.00%
1	138	30,305,849	263.436	4277	2358	708	94	0.00%
1	138	30,305,849	263.779	4277	2358	708	95	0.00%
1	138	30,305,849	263.723	4277	2358	708	96	0.00%
1	138	30,305,849	264.012	4277	2358	708	97	0.00%
1	138	30,305,849	263.709	4277	2358	708	98	0.00%
1	138	30,305,849	263.754	4277	2358	708	99	0.00%
1	138	30,305,849	263.938	4277	2358	708	100	0.00%
1	138	30,305,849	263.338	4277	2358	708	101	0.00%
1	138	30,305,849	263.064	4277	2358	708	102	0.00%
1	138	30,305,849	263.666	4277	2358	708	103	0.00%
1	138	30,305,849	263.188	4277	2358	708	104	0.00%
1	138	30,305,849	263.661	4277	2358	708	107	0.00%
1	138	30,305,849	263.435	4277	2358	708	108	0.00%
1	138	30,305,849	263.56	4277	2358	708	109	0.00%
1	138	30,305,849	263.986	4277	2358	708	110	0.00%
1	138	30,305,849	263.61	4277	2358	708	113	0.00%
1	138	30,305,849	263.51	4277	2358	708	114	0.00%
1	138	30,305,849	263.085	4277	2358	708	116	0.00%
1	138	30,305,849	264.145	4277	2358	708	117	0.00%
1	138	30,305,849	263.62	4277	2358	708	118	0.00%
1	138	30,305,849	264.036	4277	2358	708	119	0.00%

1	138	30,305,849	263.502	4277	2358	708	120	0.00%
1	138	30,305,849	263.431	4277	2358	708	121	0.00%
1	138	30,305,849	264.053	4277	2358	708	122	0.00%
1	138	30,305,849	264.163	4277	2358	708	123	0.00%
1	138	30,305,849	263.684	4277	2358	708	124	0.00%
1	138	30,305,849	263.423	4277	2358	708	125	0.00%
1	138	30,305,849	263.92	4277	2358	708	126	0.00%
1	138	30,305,849	263.277	4277	2358	708	127	0.00%
1	138	30,305,849	263.655	4277	2358	708	128	0.00%
1	138	30,305,849	263.7	4277	2358	708	129	0.00%
1	138	30,305,849	263.868	4277	2358	708	130	0.00%
1	138	30,305,849	263.327	4277	2358	708	131	0.00%
1	138	30,305,849	264.059	4277	2358	708	133	0.00%
1	138	30,305,849	263.684	4277	2358	708	134	0.00%
1	138	30,305,849	263.684	4277	2358	708	135	0.00%
1	138	30,305,849	263.953	4277	2358	708	136	0.00%
1	138	30,305,849	264.125	4277	2358	708	138	0.00%
1	138	30,293,679	264.192	4712	1844	774	53	-0.04%
1	138	30,291,937	264.034	4765	1889	733	51	-0.05%
1	138	30,281,072	263.734	3383	1689	562	31	-0.08%
1	138	30,244,524	263.655	3030	1564	768	30	-0.20%
1	138	30,235,520	263.755	4351	1983	1109	7	-0.23%
1	138	30,218,314	263.854	3748	2278	821	61	-0.29%
1	138	30,213,409	263.982	5262	2192	353	4	-0.31%
1	138	30,212,876	264.161	5255	1485	484	48	-0.31%
1	138	30,203,048	263.998	3339	2061	803	50	-0.34%
1	138	30,189,820	264.345	4383	2563	795	68	-0.38%
1	138	30,184,480	264.025	4354	2012	926	43	-0.40%
1	138	30,183,503	263.658	3984	2036	696	20	-0.40%
1	138	30,180,546	263.745	4137	1379	1149	9	-0.41%
1	138	30,180,400	264.41	4105	2823	498	18	-0.41%
1	138	30,180,400	263.607	3877	2698	1004	45	-0.41%
1	138	30,177,236	264.353	3977	1829	1041	42	-0.42%
1	138	30,161,317	264.358	4269	1350	836	77	-0.48%
1	138	30,149,562	263.758	3938	2132	630	63	-0.52%
1	138	30,146,566	263.409	3903	2773	550	38	-0.53%
1	138	30,118,888	264.095	4249	2012	1227	47	-0.62%
1	138	30,117,899	264.402	4088	2504	733	26	-0.62%
1	138	30,117,899	264.413	4333	1875	493	72	-0.62%
1	138	30,117,899	264.078	4083	2377	868	74	-0.62%
1	138	30,100,046	263.556	4459	2430	726	84	-0.68%

1	138	30,035,297	263.679	3718	2700	977	2	-0.89%
1	138	30,032,194	264.363	4462	2530	522	59	-0.90%
1	138	30,006,257	263.887	4011	1780	722	82	-0.99%
1	138	30,000,930	264.036	5347	2442	864	29	-1.01%
1	138	29,964,049	263.961	3713	2376	707	69	-1.13%
1	138	29,946,990	264.532	2938	2131	924	49	-1.18%
1	138	29,941,342	263.164	3048	2962	424	60	-1.20%
1	138	29,940,461	264.201	3948	2642	863	73	-1.21%
1	138	29,913,429	264.369	4307	2279	933	52	-1.29%
1	138	29,913,182	263.339	4097	2131	1123	56	-1.30%
1	138	29,899,607	263.845	4088	2925	710	14	-1.34%
1	138	29,827,295	263.481	3917	2202	1124	5	-1.58%

Table A.12. Full Results for Instance with 10% Budget Decrease and 15 Dredges

Experiment No	Number of RPs	Objective Function Value (cubic yards)	Solution Time (sec)	Total Dredge Time (sec)	Total Travel Time (sec)	Total Idle Time (sec)	RP	% Change
1	138	35,567,803	261.205	3040	1446	344	19	16.74%
1	138	32,925,314	261.097	2698	1549	367	17	8.07%
1	138	32,502,936	261.203	2650	1794	504	11	6.68%
1	138	32,311,858	261.114	2550	1881	426	6	6.06%
1	138	31,398,057	261.296	2542	1188	615	58	3.06%
1	138	31,378,418	261.245	2520	1345	435	57	2.99%
1	138	31,021,414	261.138	2715	1347	346	40	1.82%
1	138	30,980,437	261.205	2508	1866	391	39	1.69%
1	138	30,804,612	261.155	2499	1428	251	37	1.11%
1	138	30,772,546	261.13	2426	1611	172	36	1.00%
1	138	30,645,656	261.138	2435	1819	185	33	0.59%
1	138	30,556,935	261.644	2461	2036	411	45	0.30%
1	138	30,555,498	261.262	2538	1589	475	24	0.29%
1	138	30,552,395	261.091	2489	1303	575	25	0.28%
1	138	30,552,395	261.54	2735	1604	262	49	0.28%
1	138	30,552,395	261.502	2501	1442	478	56	0.28%
1	138	30,544,644	261.165	2565	1228	604	28	0.26%
1	138	30,544,644	261.257	2424	2066	584	86	0.26%
1	138	30,539,682	261.123	2312	1689	287	7	0.24%
1	138	30,539,682	261.245	2681	1788	481	47	0.24%
1	138	30,539,682	261.053	2449	1433	459	59	0.24%
1	138	30,539,682	261.308	2491	1206	349	68	0.24%
1	138	30,539,682	261.139	2625	2015	416	70	0.24%

1	138	30,539,186	261.116	2511	1645	339	1	0.24%
1	138	30,537,471	261.294	2530	2231	265	29	0.23%
1	138	30,537,471	261.173	2543	1536	633	54	0.23%
1	138	30,537,471	261.287	2540	2014	388	80	0.23%
1	138	30,536,461	261.191	2564	2247	361	14	0.23%
1	138	30,536,461	261.12	2401	1324	555	83	0.23%
1	138	30,535,189	261.132	2603	1773	302	4	0.23%
1	138	30,535,189	261.242	2223	1487	289	20	0.23%
1	138	30,535,189	261.253	2461	2041	356	41	0.23%
1	138	30,535,189	261.157	2540	1532	586	52	0.23%
1	138	30,535,189	261.341	2474	1549	208	63	0.23%
1	138	30,531,698	261.225	2424	1322	303	3	0.21%
1	138	30,528,853	261.555	2617	2006	195	74	0.20%
1	138	30,525,888	261.006	2620	1500	479	72	0.19%
1	138	30,525,888	261.319	2478	2124	311	73	0.19%
1	138	30,525,888	261.157	2526	1861	463	82	0.19%
1	138	30,525,684	261.393	2539	1589	477	8	0.19%
1	138	30,525,684	261.051	2400	1788	507	23	0.19%
1	138	30,525,041	261.449	2559	2020	506	87	0.19%
1	138	30,523,990	261	2449	1472	397	13	0.19%
1	138	30,523,990	261.124	2498	1435	504	16	0.19%
1	138	30,522,914	261.404	2554	1039	621	65	0.19%
1	138	30,522,526	261.036	2574	1332	609	27	0.18%
1	138	30,517,037	261.212	2401	1023	305	60	0.17%
1	138	30,515,190	261.335	2464	1035	790	5	0.16%
1	138	30,511,601	261.493	2467	1574	416	61	0.15%
1	138	30,509,036	261.206	2470	1748	291	79	0.14%
1	138	30,508,818	261.069	2587	1624	221	77	0.14%
1	138	30,504,559	261.39	2428	1295	691	53	0.12%
1	138	30,503,098	261.1	2541	1558	226	50	0.12%
1	138	30,502,923	261.104	2505	1796	252	43	0.12%
1	138	30,497,275	261.505	2476	1854	187	30	0.10%
1	138	30,497,275	261.443	2614	1930	249	66	0.10%
1	138	30,496,394	261.141	2479	1117	910	71	0.10%
1	138	30,489,695	261.066	2547	1726	222	42	0.08%
1	138	30,476,623	260.989	2463	1716	437	75	0.03%
1	138	30,473,558	261.312	2578	2065	248	15	0.02%
1	138	30,472,321	261.808	2502	1365	369	76	0.02%
1	138	30,466,525	261.115	2499	1793	275	0	0.00%
1	138	30,466,525	261.525	2499	1793	275	10	0.00%
1	138	30,466,525	261.156	2499	1793	275	12	0.00%

1	138	30,466,525	261.027	2499	1793	275	21	0.00%
1	138	30,466,525	261.363	2499	1793	275	22	0.00%
1	138	30,466,525	261.131	2499	1793	275	34	0.00%
1	138	30,466,525	261.183	2499	1793	275	35	0.00%
1	138	30,466,525	261.252	2499	1793	275	46	0.00%
1	138	30,466,525	261.243	2499	1793	275	55	0.00%
1	138	30,466,525	261.2	2499	1793	275	62	0.00%
1	138	30,466,525	261.367	2499	1793	275	64	0.00%
1	138	30,466,525	261.228	2499	1793	275	67	0.00%
1	138	30,466,525	261.159	2499	1793	275	78	0.00%
1	138	30,466,525	261.102	2499	1793	275	81	0.00%
1	138	30,466,525	261.181	2499	1793	275	90	0.00%
1	138	30,466,525	261.241	2499	1793	275	91	0.00%
1	138	30,466,525	261.316	2499	1793	275	92	0.00%
1	138	30,466,525	261.591	2499	1793	275	93	0.00%
1	138	30,466,525	261.202	2499	1793	275	94	0.00%
1	138	30,466,525	261.134	2499	1793	275	95	0.00%
1	138	30,466,525	261.074	2499	1793	275	96	0.00%
1	138	30,466,525	261.159	2499	1793	275	97	0.00%
1	138	30,466,525	261.649	2499	1793	275	98	0.00%
1	138	30,466,525	261.175	2499	1793	275	99	0.00%
1	138	30,466,525	261.168	2499	1793	275	100	0.00%
1	138	30,466,525	261.107	2499	1793	275	101	0.00%
1	138	30,466,525	261.465	2499	1793	275	102	0.00%
1	138	30,466,525	261.271	2499	1793	275	103	0.00%
1	138	30,466,525	261.317	2499	1793	275	104	0.00%
1	138	30,466,525	261.229	2499	1793	275	105	0.00%
1	138	30,466,525	261.634	2499	1793	275	106	0.00%
1	138	30,466,525	261.577	2499	1793	275	107	0.00%
1	138	30,466,525	261.511	2499	1793	275	108	0.00%
1	138	30,466,525	261.241	2499	1793	275	109	0.00%
1	138	30,466,525	261.3	2499	1793	275	110	0.00%
1	138	30,466,525	261.501	2499	1793	275	111	0.00%
1	138	30,466,525	261.128	2499	1793	275	112	0.00%
1	138	30,466,525	261.547	2499	1793	275	113	0.00%
1	138	30,466,525	261.431	2499	1793	275	114	0.00%
1	138	30,466,525	261.095	2499	1793	275	115	0.00%
1	138	30,466,525	261.299	2499	1793	275	116	0.00%
1	138	30,466,525	261.429	2499	1793	275	117	0.00%
1	138	30,466,525	261.219	2499	1793	275	118	0.00%
1	138	30,466,525	261.406	2499	1793	275	119	0.00%

1	138	30,466,525	261.315	2499	1793	275	120	0.00%
1	138	30,466,525	261.659	2499	1793	275	121	0.00%
1	138	30,466,525	261.214	2499	1793	275	122	0.00%
1	138	30,466,525	261.687	2499	1793	275	123	0.00%
1	138	30,466,525	261.345	2499	1793	275	124	0.00%
1	138	30,466,525	261.442	2499	1793	275	125	0.00%
1	138	30,466,525	261.343	2499	1793	275	126	0.00%
1	138	30,466,525	261.272	2499	1793	275	127	0.00%
1	138	30,466,525	261.343	2499	1793	275	128	0.00%
1	138	30,466,525	261.303	2499	1793	275	129	0.00%
1	138	30,466,525	261.303	2499	1793	275	130	0.00%
1	138	30,466,525	261.696	2499	1793	275	131	0.00%
1	138	30,466,525	261.399	2499	1793	275	132	0.00%
1	138	30,466,525	261.337	2499	1793	275	133	0.00%
1	138	30,466,525	261.502	2499	1793	275	134	0.00%
1	138	30,466,525	261.262	2499	1793	275	135	0.00%
1	138	30,466,525	261.281	2499	1793	275	136	0.00%
1	138	30,466,525	261.376	2499	1793	275	137	0.00%
1	138	30,466,525	261.511	2499	1793	275	138	0.00%
1	138	30,464,791	261.148	2369	2049	299	32	-0.01%
1	138	30,462,325	261.135	2581	2197	145	48	-0.01%
1	138	30,454,198	260.967	2451	1804	296	38	-0.04%
1	138	30,426,287	261.203	2444	1523	305	31	-0.13%
1	138	30,410,394	261.463	2635	2021	233	51	-0.18%
1	138	30,307,554	261.35	2428	1464	491	89	-0.52%
1	138	30,245,821	261.112	2380	1923	531	69	-0.72%
1	138	30,245,821	261.109	2479	2109	203	88	-0.72%
1	138	30,229,872	261.434	2621	2400	144	44	-0.78%
1	138	30,229,464	261.186	2501	1916	541	9	-0.78%
1	138	30,225,159	261.319	2399	1517	376	85	-0.79%
1	138	30,220,462	261.323	2440	1389	431	18	-0.81%
1	138	30,215,979	261.369	2587	1775	507	84	-0.82%
1	138	30,212,876	261.182	2551	1958	347	26	-0.83%
1	138	30,037,842	261.702	2513	2132	346	2	-1.41%

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